tempting to avoid enemy air defenses might reduce the effectiveness of attacking aircraft, it will certainly allow them to survive longer. Passive acquisition systems, such as FLIRs and televisions, on the other hand, do not provide warning to attacking aircraft, and thus afford the air defender an element of surprise and stealth. In conclusion, equipping all individual air defense units with active radar sensors could be an expensive proposition that might provide only limited useful added capability over cheaper passive sensors.

Additional Desirable Characteristics

Both helicopters and fighter bombers attacking armored formations in the extremely hazardous environment of the forward battle area would attempt to minimize their vulnerability to enemy air defenses by employing tactics that would limit the time they were exposed to air defense sensors. Thus, the period available for air defense reaction would be short. As a consequence, whatever munition--be it missile or anti-aircraft round--that is employed to destroy the aircraft would have to traverse the distance from the air defense unit to the target quickly, so that it would arrive before the aircraft has a chance to duck behind hills, buildings, or trees.

Moreover, attacking aircraft would employ maneuvers and use passive and active countermeasures to elude the air defense's systems for locating targets and guiding missiles to their targets. Evasive maneuvers employing rapid, jerky turns are particularly effective against air defense systems with unguided munitions. Dropping infrared flares and suppressing aircraft heat signatures (such as engine exhaust) are common measures employed against infrared sensors and missiles. Thus, the munition might need guidance as it nears its target in order to have a high probability of hitting aircraft that are maneuvering or are a long way from the firing unit. For maximum effectiveness, this "terminal guidance" should not rely solely on either radar or infrared means. Instead, it might use a combination of the two, or rely on commands from the gunner transmitted by wire, radio link, or laser beam.

Although most Soviet helicopters and fighter bombers are not currently capable of operating effectively at night, new systems entering the inventory, such as the Havoc attack helicopter and the Frogfoot close air support aircraft, will probably be equipped with FLIRs and will have some ability to operate in darkness. Therefore, any new U.S. air defense system designed to overcome these new threats must not rely solely on visual means for locating targets, but should also include a sensor capable of detecting aircraft in darkness.

Two final characteristics that are desirable in forward area air defense systems are found in almost all weapons positioned close to the front lines--mobility and light armor protection from small arms fire and artillery fragments. A system providing air defense for the maneuver elements must be able to accompany the vehicles that make up the fighting force. Therefore, it must have mobility and survivability characteristics similar to the weapons that it is protecting.

CHAPTER III

CURRENT U.S. AIR DEFENSE SYSTEMS AND THEIR CAPABILITIES

The Army's heavy divisions currently include many types of weapons, some of which are dedicated solely to the air defense mission. In addition, some of the weapons that are not designed primarily to destroy enemy aircraft could do so under certain circumstances. The ability of a heavy division to protect itself from air attack depends on the total contributions from each of the many different types of weapons within the division.

One means of gauging an Army force's ability to defend itself from air attack would be to count the total number of weapons in that force that could locate and fire upon an attacking enemy aircraft. The supposition is that the more U.S. weapons capable of attacking enemy aircraft, the better. This chapter describes the weapons in a typical heavy division that would make up the forces deployed closest to the front. It also examines and evaluates the ability of each of those weapons to destroy enemy aircraft, particularly standoff helicopters.

CURRENT U.S. SYSTEMS

The Army's armored and mechanized divisions currently include three weapon systems dedicated solely to air defense: Chaparral, Vulcan, and Stinger. The mission of these systems is to protect the forward half of the division (within about 10 kilometers of the front line) from aerial attack. In addition, each division includes many M1 tanks and fighting vehicles. Although these weapons are not specifically designed to engage aircraft, they do have some residual capability against airborne targets, particularly hovering helicopters. A detailed discussion of the characteristics of these various systems follows.

Chaparral

First deployed in 1966, Chaparral is a guided missile system that is effective against both high-speed, fixed-wing aircraft and slower moving or hovering helicopters. Chaparral consists of a launching station and infrared target sensor mounted on a tracked vehicle. Four missiles with infrared seekers and an effective range of about five km can be mounted and carried on the launch rails. Eight more missiles can be carried in the vehicle, providing two reloads. The time needed to mount four new missiles on the rails is about eight minutes.

The original version of Chaparral had no means of detecting targets other than the crew's eyesight, which severely limited the ability of the system to operate at night or in bad weather. In order to remedy this deficiency, the 500 or so Chaparral fire units now in the Army's inventory are being equipped with Forward Looking Infrared Sensors (FLIRs) to provide the gunner with the ability to find targets at night and in adverse weather.

The Chaparral's infrared missile is guided to its target by the heat emitted by the engines of the attacking aircraft. The missile seeker finds and locks-on to its target before it is launched from the Chaparral unit. The maximum range from launcher to target at time of launch is determined by when the missile's seeker can "sense" the heat emanating from its target. This range varies greatly with the position and nature of the target, since it is easier to sense the heat from the engines of a receding high-performance aircraft than it is to detect the heat from those of a face-on hovering helicopter. Thus, the five km range cited by various sources could be reduced somewhat (to about three to four km) against hovering helicopters or increased against departing fighter bombers.

Chaparral was not designed to survive in the extremely hazardous environment of the most forward area of the division. Its mission is limited to defending stationary assets, such as command posts, supply points, and field artillery emplacements--typically located at least five km from the front--because the Army feels that placing Chaparral firing units closer to the front lines and enemy artillery would endanger their survivability. Although Chaparral units are currently being removed from the heavy divisions and placed directly under the control of the corps--the managerial unit directly above the divisions--their primary mission will still be to support the divisions within each corps.

Vulcan

The Vulcan anti-aircraft gun was introduced into the Army's inventory at the same time as Chaparral and, in the heavy divisions, is mounted on a self-propelled vehicle equipped with tracks. Its six-barrel, 20mm gun is a rapid fire "Gatling" type that is effective against both fixed-wing aircraft and helicopters up to ranges of 1,200 meters. Although it is equipped with a night sight, the Vulcan system does not include a FLIR and is, therefore, incapable of operating in adverse weather. Each division currently includes 24 Vulcan guns to be used in support of the maneuver units. An illustrative battalion-sized task force, which might contain 19 tanks and 30 infantry fighting vehicles, would be accompanied by four Vulcans. The Vulcans can move with the units and would be positioned so that two-thirds of their effective range extends in front of the defended force. Vulcan's primary limitation, particularly against standoff helicopters, is its short range.

Stinger

Stinger is a small, portable air defense weapon that fires an infrared missile, similar to Chaparral's, and is launched from a soldier's shoulder. The gunner must detect targets using eyesight only, thus limiting Stinger's usefulness to daytime and good weather. Stinger's maximum range is comparable to that of Chaparral, and could be as much as six km when fired at most fixed-wing aircraft. Its range would be reduced to three to four km against hovering helicopters, however.

Each armored and mechanized division currently includes 60 Stinger teams, each composed of two soldiers equipped with a jeep, six missiles, and communitions equipment. (A typical battalion-sized task force might include four Stinger teams.) Since Stinger is a small, highly mobile system, it can travel with the maneuver units and provide flexible, widely dispersed air defense. Because Stinger cannot be fired from inside a vehicle, the gunner could be exposed to enemy fire whenever he dismounts to fire at approaching enemy aircraft. This liability, and Stinger's limited range against hovering helicopters are its main drawbacks.

The Bradley Fighting Vehicle (BFV) and Improved TOW Vehicle (ITV)

These two lightly armored vehicles provide additional antitank capability to the armored and mechanized divisions. The Improved TOW Vehicle (ITV) is a converted M113 personnel carrier equipped with a TOW antitank missile launcher and its associated optical day and night sights. It is used solely to destroy enemy tanks and does not transport soldiers. The Bradley is a new personnel carrier designed to carry troops onto the battlefield where they can support the more heavily armored main battle tanks. It is also equipped with a TOW missile launcher plus a 25mm cannon.

The TOW missile has a maximum effective range of almost four km. It is guided by commands transmitted from the gunner through a wire that is played out as the missile flies toward its target. It is a rather slow missile, taking 15 seconds to reach its maximum range of 3,750 meters, and must be guided all the way to its target. Because TOW was not designed to attack fast-moving targets, it is ineffective against fixed-wing aircraft or even helicopters traversing at high speed. Against hovering helicopters, however, it could be a formidable weapon, even though it was designed to be and is primarily used as an antitank weapon.

The Bradley also carries a 25mm gun, with an effective range of about two km. Because the Bradley cannot compute appropriate lead angles for moving targets or ranges to any targets, the 25mm gun is not very useful against fast-moving airplanes. Within its range of two km, however, the gun could be used effectively against relatively stationary aircraft, such as hovering helicopters.

Each heavy division includes a total of 376 to 430 Bradleys and ITVs. Although the primary role of these vehicles is not air defense, their weapons could certainly be used in self-defense against an attacking helicopter or against any aircraft that should suddenly come within the weapons' range.

M1 Abrams Tank

Each armored or mechanized division also includes between 290 and 350 M1 tanks. The latest A1 version of the tank includes a 120mm gun with a maximum effective range against ground targets of three km. Against aircraft, the range would probably be diminished somewhat, to two to two and a half km. The tank's fire control system can establish range to the target and compensate for slowly moving targets. It cannot, however, adjust for targets moving up or down. Although designed and used primarily for other purposes, the tank's main gun could be used against hovering helicopters, especially in self-defense.

CAPABILITIES OF CURRENT U.S. SYSTEMS

The characteristics necessary for successful air defense against standoff helicopters were identified and discussed in the previous chapter. Table 2 presents a comparison of the characteristics of the weapon systems currently in the Army's armored and mechanized divisions with those that were determined to be desirable when combatting the Soviet helicopter threat. It can be seen from the table that none of the current systems possesses all the desired characteristics.

Limited range is the main drawback of all current systems. Not one has the seven to eight km effective range needed to engage helicopters standing off at distances that would be expected during a Central European battle. Further, none of the dedicated air defense systems are present in

TABLE 2. CAPABILITIES OF CURRENT U.S. AIR DEFENSE SYSTEMS

	Dedicated Air Defense Systems			Armored Fighting Weapons	
Capability a/	Vulcan	Chaparral	Stinger	TOW b/	Tank
Range 7 to 8km	No	No	No	No	No
Adequate Numbers (70-80 per Division)	No	No	No	Yes	Yes
Inexpensive (Relative to DIVAD)	Yes	Yes	Yes	Yes	Yes
Rapid Destruction Capability (Relative to TOW)	Yes	Yes	Yes	c/	Yes
Guided	No	Yes	Yes	Yes	No
Resistant to Counter Measures	Yes	No d/	No d/	Yes e/	Yes
Night Capability	No	Yes	No	Yes	Yes

SOURCE: Compiled by Congressional Budget Office from various Department of the Army documents including Department of the Army, *United States Army Weapons Systems 1986* (January 1986); and Department of the Army Field Manuals *FM 44-3, 44-18, 77-2J.*

a. Two additional characteristics were identified in the previous chapter: mobility and protection from small arms and artillery. All of the systems listed in the table are mobile. All are also protected, except for Stinger.

b. On Bradley Fighting Vehicles and Improved TOW Vehicles.

c. Not applicable.

d. New versions of the Chaparral and Stinger missiles include improved seekers (Rosette Scan Seeker and the POST seeker, respectively) with increased resistance to countermeasures.

e. The latest version of the TOW missile, TOW II, is relatively resistant to countermeasures such as smoke and flares, but is too slow to follow a rapidly maneuvering aircraft.

the armored or mechanized divisions in sufficient number (70 to 80) to provide an adequate air defense against low-altitude helicopters. The only numerous systems within the armored and mechanized divisions are the TOW missile launchers on the Bradleys and ITVs (376-430) and M1 tanks (290-350) for whom air defense is secondary. Finally, most of the current systems can destroy targets quickly (except for TOW) and some also can operate at night. Only the TOW missile, however, is both guided--and, therefore, able to hit long-range or slowly maneuvering targets--and resistant to countermeasures.

Measuring Total Air Defense Capability

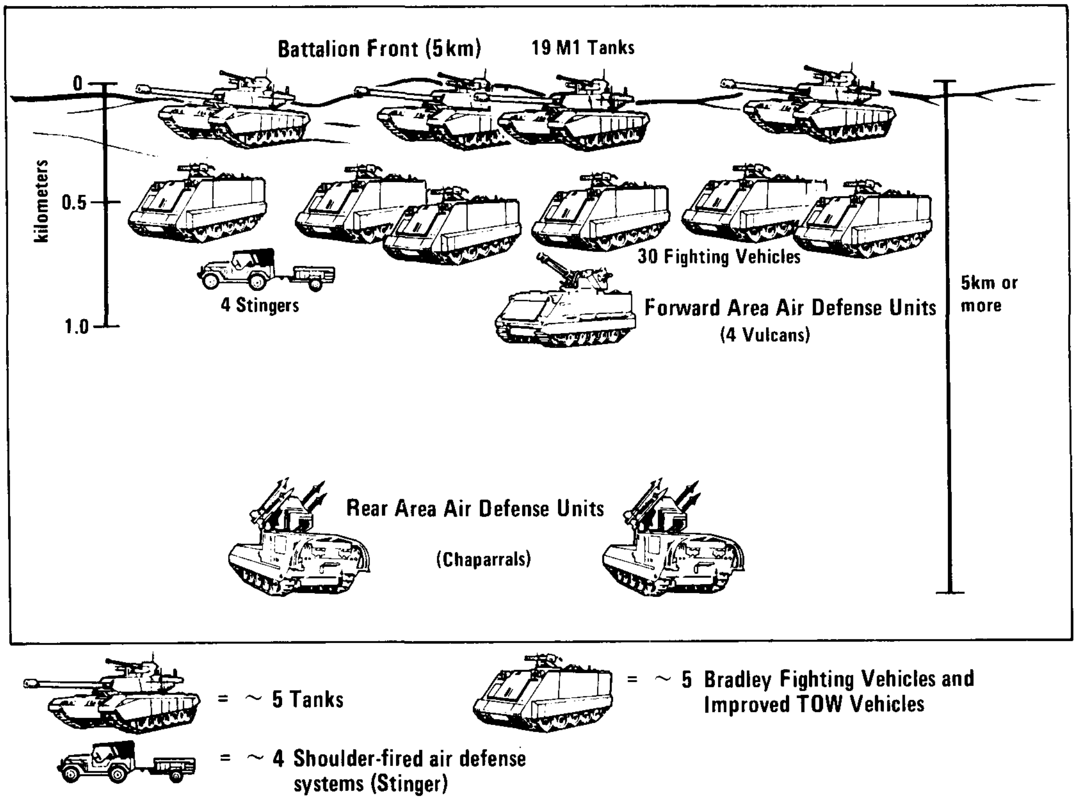
Although an Army unit is made up of individual weapons, the total capability of the entire unit acting in concert is not necessarily equal to the sum of all the individual capabilities. The total impact of the force might be less, because of overlap or redundancy of the individual systems, or more, because of synergistic effects. Furthermore, the contribution of each individual system could be affected by its placement on the battlefield or its ability to communicate with other systems. For this reason, a measure is needed of the effectiveness of an entire Army unit to defend itself from air attack while engaged in battle in Central Europe.

One measure that can be used to gauge the relative air defense potential of various forces or collections of weapon systems is the total number of potential engagements that a force might have against aircraft attacking the forward maneuver elements. The discussion of the air threat in Chapter II pointed out the altitude and standoff advantage that helicopters have over fixed-wing aircraft when attacking armored targets. Thus, the measure used in this study emphasizes the ability to defend against standoff helicopters.

Potential Engagements

Specifically, this study calculates the number of engagements that a battalion-sized task force could expect to complete against helicopters hovering at various ranges. The task force was assumed to be deployed in central Germany on typically hilly terrain. The tanks in the force were assumed to be the most forward element, and were dispersed uniformly along the front. The fighting vehicles, including Bradleys and ITVs, were assumed to be deployed uniformly along a line parallel to and 0.5 km behind the front. Shoulder-fired air defenses, such as Stingers, were deployed uniformly at the same depth as the Bradleys. The forward air defense units (Vulcan guns, for example) were assumed to be deployed uniformly along a line one km behind the tanks. Chaparral units were positioned at least five

Figure 7.
Typical Weapon System Deployment for Battalion-Sized Force



SOURCE: Congressional Budget Office, based on scenario used in Department of the Army, TRADOC Studies and Analysis Agency (TRASANA) Sgt York Alternatives Analysis (October 1985).

km to the rear of the tanks (see Figure 7). 1/ The total frontage of the battalion was assumed to be five km. Obviously these assumptions--as with many other in this analysis--will not predict or represent all of the characteristics of a specific battlefield. They are, however, reasonable simplifications.

1. The placement of weapons on the battlefield is representative of Army practices as outlined in Field Manuals FM 44-3, 44-18, and 71-2J. The impact of an altered weapons placement on the ultimate measured capability would not be significant.

Enemy helicopters were assumed to attack the center of the battalion from various standoff ranges (as measured from the tanks) and to fire their weapons while hovering at 20m altitude. The number of each type of weapon within range of each hovering helicopter was then calculated, taking into account the maximum range capability of each of the weapon systems. Assuming clear weather conditions with a visibility of seven km, the number of those weapon systems within range and with at least a 50 percent probability of line of sight to the helicopter was then determined (for example, the number of Bradleys within range of the helicopters multiplied by the probability of line of sight to helicopters five and one-half km away). The total number of potential engagements by the battalion task force against helicopters at varying standoff ranges was then determined by summing up the engagements by each of the various types of weapons. This defined the total potential engagements.

By measuring the total potential engagements, the maximum air defense capability of a battalion task force can be evaluated and used to compare the air defense potential of differing combinations of weapons. The possible contribution of all weapons is taken into account, as well as the effects of terrain and the relative positioning of the various types of weapons dictated by survivability constraints.

Because of all the assumptions necessary to simplify the actual conditions that might exist on a battlefield, however, this measure cannot be viewed as an absolute one--that is, the measure used in this study cannot be used to predict the outcome of an actual U.S.-Soviet confrontation in Central Europe. Rather, the measure should be used to compare the relative performance of various weapons combinations against standoff helicopters.

Limitations of the Measurement Analysis

While the measurement of total potential engagements provides a very useful evaluation of air defense capability, it does omit some pertinent factors. These include target detection ability, reaction time, and target destruction; the possible development of an air defense system that would not require line-of-sight target acquisition; and lack of engagement analysis against fixed-wing aircraft.

System Detection Capability, Reaction Time, Destructiveness. Several factors that could affect the ultimate air defense capability of an armored force are not captured by measuring total potential engagements. The ability of an individual weapon unit to convert potential engagements to aircraft destruction is assumed to be the same for all weapon systems. This assumption ignores the several steps that must be accomplished from establishing line of sight to an attacking helicopter to destroying it. First, the air defense gunner must detect the helicopter--that is, distinguish the attacking helicopter from its background. Most modern air defense systems include some kind of sensor--radar, infrared or magnified visual--to help the gunner spot attacking aircraft. Radar systems are for the most part the most efficient since they can easily and quickly scan the total 360° surrounding the unit (for example, the DIVAD radar made a complete 360° scan every two seconds). Furthermore, radar return signals are processed electronically for any reflections that might represent targets. Detection of a target by radar is, therefore, automatic and does not require human interpretation to distinguish a target from the background.

On the other hand, infrared and optical systems--known as passive systems--are typically limited to viewing a small sector (45°, for example) at a time, and generally do not scan the entire 360°. Furthermore, signals are not processed electronically, nor targets identified automatically. Rather, an image like a television picture is produced, and a crew member must constantly watch the screen to see if a target appears. Thus, should a target appear somewhere besides where the sensor is looking, or should a target appear on the screen and the crew member not recognize it as such, a helicopter could go undetected.

A partial solution to the limitations of passive systems--limited coverage and nonautomated target recognition--would be to provide information on target presence and general location to the air defense units equipped with passive sensors. In this way, the passive sensors could be pointed in the correct direction and crew members alerted to the presence of a target. This process, called "cueing" or "alerting," obviously requires input from some system that can automatically detect targets appearing anywhere within 360°. One approach would be to deploy a small number of radars with a much greater number of air defense units (for example, eight radars per 36 or 72 air defense units) to alert the air defense weapons when an air attack commenced.

With cueing, passive systems should be able to respond to an air attack as reliably and quickly as those equipped with radar, although the cost of providing cueing radars would also have to be taken into account. Therefore, the ability of different weapon systems, which rely variously upon radar, FLIRs, optical systems, or unaided eyesight, to detect low-altitude helicopters out to ranges of seven km was assumed to be roughly equal.

Second, air defense missiles or anti-aircraft rounds must reach the helicopter before it completes its task and remasks. The time needed to react to a detected helicopter, pull the trigger, and fly the missile or bullet to the helicopter, was assumed to be about the same for all systems considered. Furthermore, all systems were assumed to react quickly enough to engage all potential targets.

Finally, the bullet or missile must arrive at the target and explode, causing lethal damage. This analysis assumed that, given an engagement opportunity within a system's effective range, all the systems studied had a roughly equivalent likelihood of destroying the target.

The total number of engagements is still a useful measure even if all these assumptions are not strictly valid. Differences in detection capability, reaction time, and munition effectiveness do, of course, exist among specific weapons systems. These differences, however, would be of no consequence if the weapon were not in position to detect and engage the attacker in the first place. Further, since the measure defined here is used only to establish relative performance of various force mixes, small differences among specific systems would not affect the respective rankings.

Non-Line-of-Sight Air Defense Systems. The measure of effectiveness used in this analysis assumes that an enemy helicopter must see its target in order to attack it and, conversely, that the air defender must see the helicopter to engage it. This measure obviously would not be appropriate for an air defense system that did not have to see its target (helicopter or fighter bomber) in order to engage it. Although the Army does not currently have such a system in its inventory, it does have prototypes of a missile capable of attacking targets behind hills or trees. While such a "non-line-of-sight" (NLOS) air defense system might be readily available within the next five to ten years, it probably would not be able to contribute significantly to air defense capabilities during the more immediate period that is the focus of this study.

Another factor arguing against the relevance of a NLOS air defense system to this study is the absence of a Soviet weapon that a helicopter or fighter bomber could deliver without the attacking aircraft's exposing itself. In other words, current Soviet antiarmor munitions require the attacking aircraft to see its target before launching its weapon. Indeed, in the case of the AT-6 antitank missile currently used by Soviet helicopters, the helicopter must guide the missile all the way to impact. This requires that the helicopter maintain line of sight to the target throughout the entire missile flight. Although a missile has been postulated for enemy helicopters that would allow the launching aircraft to remain hidden behind hills while lobbing its missiles at a target designated by some other enemy platform, no mention has been made in unclassified literature of such weapons in the Soviet inventory to date. It is, therefore, unlikely that such a threat would materialize in any significant way before the mid-1990s.

A final facet of NLOS air defense systems that raises questions concerning their utility and places them outside the scope of this study is their need for general target-location information that would have to be furnished by a source other than the weapon system itself. 2/ The NLOS systems typically envisioned (and currently under study by the Army) would include a missile with some sort of seeker in its nose. The missile would be launched to the general vicinity of the target, where its integral seeker--radar or television, for example--would locate the target and guide the missile to impact.

In order to place the missile in the vicinity of the target, however, some general knowledge of the target's location would be needed. Therefore, some other sensor (an airborne radar is the one most commonly mentioned) would be required to support the NLOS air defense weapon system by initially locating the attacking aircraft. Furthermore, the information concerning the target's presence and location would have to be transmitted from the sensor to the NLOS air defense system in a timely manner. Thus, an efficient command and control system linking the sensor and air defense unit would also be required. The additional sensor and command and control network that would be required to make such a NLOS system feasible would provide the enemy with many opportunities for countering the system, such as destroying or "spoofing" the sensor or jamming communications links.

<u>Capability Against Fixed-Wing Aircraft</u>. Measuring potential engagements against hovering helicopters does nothing to evaluate a force's capability against fixed-wing aircraft. As previously stated, however, the Soviet Union--like the United States--seems to be increasing its attack helicopter inventories but not those of its ground-attack fighter bombers. In addition

2. An exception to this would be when attacking a helicopter that exposes itself for a short time and then remasks before the air defense weapon can respond. Alternative air defense solutions to remasking helicopters are shorter reaction times and faster missiles.

TABLE 3. EFFECTIVE RANGES OF CURRENT WEAPON SYSTEMS

System	Number in Task Force a/	Maximum Effective Range Against Hovering Helicopter (in kilometers)	Assumed Distance from Front Line (in kilometers)
M1 Tank	19	2-2.5	0.5
Bradley and ITV	30	3.75 (TOW)	1.0
Stinger	4	3-4	1.0
Vulcan	4	1.2	1.5
Scout Helicopter	5	None	0-0.5

SOURCE: Compiled by the Congressional Budget Office from Army data contained in various sources (see source for Table 2 on p. 25).

a. Based on the scenario used in the recent Army analysis of DIVAD alternatives, TRASANA, *Sgt. York Comparative Analysis* (October 1985).

to growing numbers, hovering standoff helicopters hold the tactical advantage over fighter bombers when attacking armored units near the front lines. Therefore, quantitative comparisons of various air defense forces based on antihelicopter capability are adequate if augmented with qualitative comparisons of effectiveness against fixed-wing aircraft.

Capability of Battalion-Sized Forces

A typical front-line, battalion-sized unit would be composed of a maneuver element containing tanks and fighting vehicles supplemented by some air defense and helicopter assets. Such a combat unit, known as a battalion task force, today might include, among other weapons, 19 M1 tanks, and 30 Bradleys and ITVs, as well as four Vulcans and four Stingers for air defense and five scout helicopters. 3/ The maximum range capability of these weapons against hovering helicopters is tabulated in Table 3.

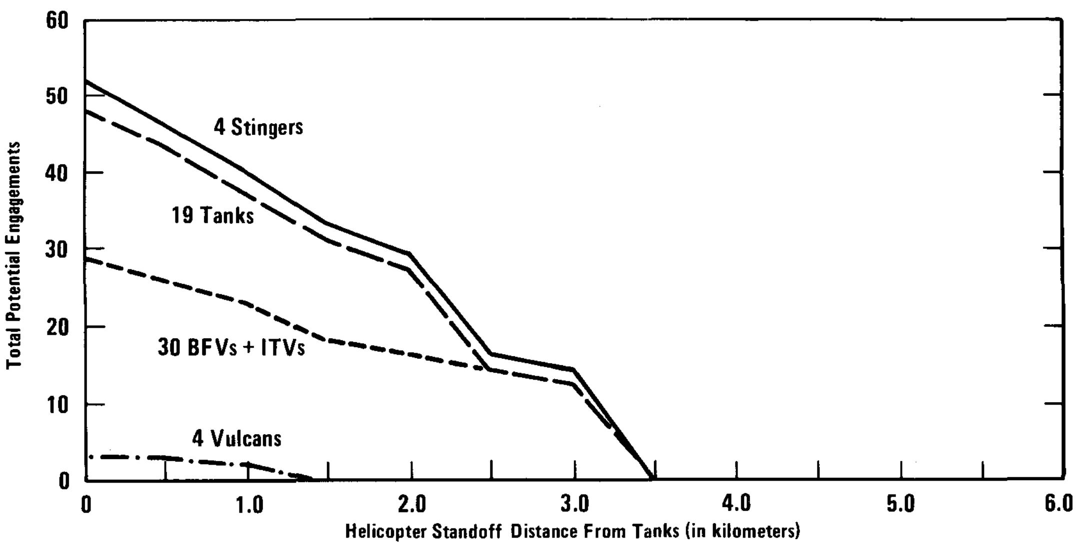
The total number of engagements that a task force composed of these weapons might have against helicopters hovering at an altitude of 20m rapidly diminishes as the standoff range of the helicopter increases (see Figure 8). With no standoff distance--that is, with the helicopter hovering directly over the target tanks--almost all of today's weapons with some air

3. Based on the battalion task force used in the Army analysis of DIVAD as reported in Department of the Army, Tradoc Studies and Analysis Agency (TRASANA), *Sgt York Comparative Analysis* (October 1985).

defense capability theoretically could engage an attacking helicopter. Under the assumptions used in this study, this would lead to a total of 52 potential engagements. As the attacking helicopters move off, however, the proportion of deployed weapons that would have line-of-sight to the aircraft, and, therefore, have a chance to see them, rapidly diminishes. Indeed, at a standoff range of one km, helicopters could be engaged by only 40 out of the total 57 weapons included in the task force. As the helicopters increased their standoff range to three km, they would be outside the reach of both the Vulcan and the tanks' guns, thus reducing the total potential engagements to 14. If enemy helicopters could standoff at ranges greater than three km and continue to attack tank formations, none of today's weapons would be able to engage them. The limited ranges of Stinger and Vulcan, in particular, in combination with the requirement that they be situated behind the most forward armor elements for their own protection,

Figure 8.

Potential Engagements of Hovering Helicopters with Current U.S. Weapons



SOURCE: Congressional Budget Office.

NOTE: Assumes enemy helicopters hover at an altitude of 20 meters.

would afford enemy helicopters an operational sanctuary at ranges between three and six km from the armored formations they would be attacking. 4/

Although not captured in the measure used here, the performance of current U.S. air defense systems, particularly Stinger and Chaparral, against fighter bombers would be much better. These two missile systems could provide a more effective defense against fighter bombers because they have a greater effective range against fixed-wing aircraft than hovering helicopters and because high-speed fighter bombers with today's weapons must come within one to two km of the armored targets they are attacking. While this is an important qualitative capability of today's systems, helicopters currently pose the greater threat.

Indeed, it was partly DIVAD's inability to defend U.S. assets from standoff helicopter attack that resulted in its demise. The need for a weapon system or systems to counter this challenging threat still exists. The next chapter examines several alternatives for improving the Army's ability to defend against standoff helicopter attack.

4. Chaparral would be situated too far to the rear to be able to engage enemy helicopters operating from their side of the front line.

CHAPTER IV

AIR DEFENSE ALTERNATIVES FOR THE MANEUVER ELEMENTS

In the previous chapter, the Army's current air defense systems were found to be deficient in defending against potential attacks by enemy helicopters armed with long-range missiles. This deficiency can be explained in part by the reliance on 20-year-old, limited range systems like Vulcan and Chaparral for air defense. The Army's modernization program, which planned to replace Vulcan with the new longer-range DIVAD gun, was seriously derailed by DIVAD's cancellation in August 1985. The Army believes, therefore, that the need for improved air defense is urgent. In light of this perceived need, this study considers only those systems that are currently available or might be available within five years. This time constraint limits candidate systems to those already in service with other nations, or at least in prototype stage.

CANDIDATES FOR DEDICATED AIR DEFENSE

Candidate systems capable of providing air defense for the maneuver units within the next five years can be divided into three general categories: anti-aircraft guns, missile systems, and hybrids. All would be dedicated solely to the air defense mission.

Guns

Anti-aircraft gun systems typically are equipped with one or two guns whose barrels have an inner diameter of 30 to 40 mm. They also usually include an acquisition and tracking radar to enable the gun to be aimed accurately at long-range or fast moving targets. Anti-aircraft guns are usually mounted on a chassis with tracks rather than wheels to facilitate movement over rough terrain. Besides the cancelled DIVAD, other modern versions include the 35mm Gepard (developed in Switzerland and in service with West German forces), and two guns not yet in service--the 30mm Wildcat (developed in West Germany) and the 40mm Trinity (developed by Bofors, a Swedish firm). The maximum effective ranges attributed to these weapons are generally four kilometers. Their costs would most likely be similar to that of the DIVAD gun, so that buying them in large numbers would require a large investment.

Missiles

Several air defense missile systems are either in service with other nations (for example, Roland with West German forces and Rapier with the British) or exist as prototypes (such as ADATS developed by a Swiss firm). These systems typically include a radar for target detection, optical or radar systems to track targets once detected, and various means for guiding the missile to the target. 1/ Most of these missile systems have sufficient range to destroy helicopters that must see their target to attack it. Furthermore, none of these systems rely upon the target's heat emissions for guidance and are, therefore, more resistant to countermeasures than Chaparral or Stinger.

All missile systems, however, require time after they have been launched to stabilize and come up to speed. Thus, they have a minimum effective range within which they cannot engage aircraft, otherwise known as a "dead zone." This might or might not be a significant problem when defending against standoff helicopters. When the cost of the accompanying missiles is taken into account, missile systems are at least as expensive as large, self-propelled, radar equipped anti-aircraft guns, requiring the same large investment for the purchase and deployment of large numbers.

Hybrids

Hybrid systems attempt to combine the advantages of gun systems and missile systems in one unit. They typically combine a small caliber gun (20 to 25mm) or hypervelocity rockets (unguided rockets capable of speeds in excess of 1,500 meters per second) with a simple missile, such as Stinger, or a small laser beam rider (for example, the Saber missile developed by Ford or the Bofors RBS-70 in use with the Swedish Army). In this way, the gun or rockets can cover the missile's inner dead zone, and the missiles can extend the range of the system beyond the gun's capability. Furthermore, systems such as General Electric's Blazer and Boeing's Avenger (which are two

1. The Roland and the Rapier missiles are like the previously described Soviet AT-6 antitank missile, in that they are directed to their targets by commands from the gunner to the missile transmitted by a radio link. ADATS is directed to its target by a laser beam shone on the target by the gunner in the fire unit. Rather than home in on laser light reflected from the target, these missiles, known as "laser beam riders," have laser detectors on their tails that can tell the missile if it is in the center of the laser beam. If not, the missile corrects itself by moving back into the middle of the beam and, thus, heads in the direction of the target.

TABLE 4. CAPABILITIES OF CANDIDATE AIR DEFENSE SYSTEMS

Capability b/	Guns (Trinity, Gepard, Wildcat)	Missiles (ADATS, Rapier, Roland)	Hybrids a/ (Blazer)
Sufficient Range (7 to 8km)	No	Yes	Yes
Cheap and Capable of Being Fielded in Large Numbers (Relative to DIVAD)	No	No	Yes
Rapid Destruction Capability	Yes	Yes	Yes
Guided to Target	No	Yes	Yes
Resistent to Counter Measures	Yes	Yes	Yes (w/missile other than Stinger)
Night Capability	Yes	Yes	Yes

SOURCE: Congressional Budget Office.

a. Mounted on a lightly armored chassis similar to the Bradley.
b. All systems are mobile and protected from small arms fire and artillery fragments.

prototype hybrid systems) generally rely on passive means for target acquisition, thus avoiding the cost of a radar. 2/ As a result they could be relatively cheap ($1.5 million to $2 million each), compared with DIVAD's $6.4 million unit price tag and a minimum of $4 million for most other gun or missile systems. Thus, it could be more feasible to buy them in large numbers.

Assessment of Candidate Air Defense Systems

When measured against the eight critieria identified in Chapter II--sufficient range, ability to field in large numbers (thus low cost), rapid destruction capability, guidance to target, resistance to countermeasures, nighttime capability, mobility, and light armor protection--air defense guns that might be available within five years fail to meet three out of eight (see Table 4). The primary shortcomings of anti-aircraft guns are their limited

2. Passive means for detecting targets include infrared sensors such as FLIRs, television cameras, and magnified optics.

range and high cost. The misssile systems have sufficient range, accuracy, and night capability and are relatively resistent to countermeasures. They too are very costly, however, and would be expensive to deploy in large numbers.

If a hybrid system were equipped with a missile that did not rely on infrared guidance (for example, a laser beam rider or one with a fiber optic command link) to avoid the possibility of infrared decoys or signature suppression, it could theoretically meet all of the outlined criteria. 3/ Although typically not equipped with radars, the individual firing units do include passive sensors such as FLIRs. When cued and alerted by early warning radars included in the divisions, even without radars, hybrid firing units should be able to detect most targets. 4/

The advantages of a hybrid system appear to be minimal for three reasons. First, the armored and mechanized divisions already include over 300 25mm guns on Bradley Fighting Vehicles. Although each individual Bradley might not be very effective against attacking helicopters, the combined impact of 300 guns would probably be more intimidating than that of the guns included on the smaller number of hybrids that would ultimately be included with each division. Secondly, the range or dead zone within which most missile systems are ineffective is at most one km. This is also the range in which a 20 or 25mm gun is most effective. It is unlikely, however, that attack helicopters would approach so closely to air defenses that are set back at least one km from the maneuver units. Furthermore, opportunities to engage attacking aircraft would occur before the aircraft approached to such short ranges. Thus, the synergistic effect of combining a gun and a missile on the same platform might be small. Lastly, the addition of a gun and its associated ammunition to a weapon system would add, unnecessarily perhaps, to the complexity and cost of that weapon. These factors, in turn, could add to the cost of purchasing and deploying sufficient numbers of a hybrid system.

IMPROVING THE AIR DEFENSE CAPABILITIES OF SYSTEMS WITH OTHER PRIMARY MISSIONS

The candidates discussed above were all dedicated to the air defense mission. Increasing the antihelicopter effectiveness of weapons with other

3. This analysis assumes that the hybrid system would not include Stinger.

4. Army divisions currently include eight Forward Area Alerting Radars (FAARs) for detecting attacking aircraft.